Claims

What is claimed is:

1. A green article comprising a powder metal mixture having a minor volume fraction of a relatively fine metal powder and a complementary major volume fraction of a relatively coarse prealloyed metal powder, wherein the relatively fine metal powder is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, and the ratio of the mean particle size of the relatively fine metal powder to the mean particle size of the relatively coarse prealloyed metal powder is at least about 1:5.

2. The green article of claim 1, wherein the relatively fine metal powder consists of two or more elemental metals or metal alloys, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

3. The green article of claim 1, wherein the relatively coarse prealloyed metal powder consists of two or more metal alloys, each of said metal alloys being amenable to supersolidus liquid phase sintering.

4. A green article comprising a powder metal mixture having a minor volume fraction of a relatively fine metal powder and a complementary major volume fraction of a relatively coarse prealloyed metal powder, wherein said minor volume fraction of a relatively fine metal powder consists of at least two sub-fractions of successively finer mean particle size, each of said successive sub-fractions consists of metal powder that is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, the ratio of the mean

particle size of the coarsest of said successive sub-fractions to the mean particle size of the relatively coarse prealloyed metal powder is at least about 1:5, and the ratio of the mean particle size of each finer successive sub-fraction to the mean particle size of an immediately preceding coarser successive sub-fraction is at least about 1:5.

5. The green article of claim 4, wherein at least one of the successive sub-fractions consists of two or more elemental metals or metal alloys, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

6. The green article of claim 4, wherein the relatively coarse prealloyed metal powder consists of two or more metal alloys, each of said metal alloys being amenable to supersolidus liquid phase sintering.

7. A method of producing a green article having an enhanced sintering temperature window, said method comprising the steps of:

a) mixing together a minor volume fraction of a relatively fine metal powder and a complementary major volume fraction of a relatively coarse prealloyed metal powder to produce a metal powder mixture; and

b) forming a green article from said metal powder mixture;

wherein the relatively fine metal is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, and the ratio of the mean particle size of the relatively fine metal powder to the mean particle size of the relatively coarse prealloyed metal powder is at least about 1:5.

8. The method of claim 7, wherein said step of forming a green article further comprises powder containerization.

9. The method of claim 7, wherein said step of forming a green article further comprises a free-forming layer-wise buildup technique.

10. The method of claim 9, wherein the free-forming layer-wise buildup technique is three-dimensional printing.

11. The method of claim 9, wherein the free-forming layer-wise buildup technique is selective laser sintering.

12. The method of claim 7, wherein said step of forming a green article further comprises metal injection molding.

13. The method of claim 7, wherein said step of forming a green article further comprises die pressing.

14. The method of claim 7, further comprising the step of providing the relatively fine metal powder, wherein the relatively fine metal powder consists of more than one elemental metal or metal alloy, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

15. The method of claim 7, further comprising the step of providing the relatively coarse prealloyed metal powder, wherein the relatively coarse prealloyed metal powder consists of more than one metal alloy, each of said metal alloys being amenable to supersolidus liquid phase sintering.

16. A method of producing a green article having an enhanced sintering temperature window, said method comprising the steps of:

a) mixing together a minor volume fraction of a relatively fine metal powder and a complementary major volume fraction of a relatively coarse prealloyed metal powder to produce a metal powder mixture; and

b) forming a green article from said metal powder mixture;

wherein said minor volume fraction of a relatively fine metal powder consists of at least two sub-fractions of successively finer mean particle size, each of said successive sub-fractions consists of metal powder that is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, the ratio of the mean particle size of the coarsest of said successive sub-fractions to the mean particle size of the relatively coarse prealloyed metal powder is at least about 1:5, and the ratio of the mean particle size of each finer successive sub-fraction to the mean particle size of an immediately preceding coarser successive sub-fraction is at least about 1:5.

17. The method of claim 16, wherein said step of forming a green article further comprises powder containerization.

18. The method of claim 16, wherein said step of forming a green article further comprises a free-forming layer-wise buildup technique.

19. The method of claim 18, wherein the free-forming layer-wise buildup technique is three-dimensional printing.

20. The method of claim 18, wherein the free-forming layer-wise buildup technique is selective laser sintering.

21. The method of claim 16, wherein said step of forming a green article further comprises metal injection molding.

22. The method of claim 16, wherein said step of forming a green article further comprises die pressing.

23. The method of claim 16, further comprising the step of providing the relatively fine metal powder, wherein at least one of the successive sub-fractions consists of two or more elemental metals or metal alloys, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

24. The method of claim 16, further comprising the step of providing the relatively coarse prealloyed metal powder, wherein the relatively coarse prealloyed metal powder consists of more than one metal alloy, each of said metal alloys being amenable to supersolidus liquid phase sintering.

25. A method of densifying a green article, said method comprising the steps of:

a) mixing together a minor volume fraction of a relatively fine metal powder and complementary major volume fraction of a relatively coarse prealloyed metal powder to produce a metal powder mixture;

b) forming a green article from said metal powder mixture;

c) heating the green article to a sintering temperature that is below the liquidus temperature of the relatively coarse prealloyed metal powder; and

d) holding the green article at said sintering temperature for a time of sufficiently long duration to densify the green article;

wherein the relatively fine metal powder is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, and the ratio of the

mean particle size of the relatively fine metal powder to the mean particle size of the relatively coarse prealloyed metal powder is at least about 1:5.

26. The method of claim 25, wherein the step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that is below the solidus temperature of the relatively coarse prealloyed metal powder.

27. The method of claim 25, wherein the step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that is between the solidus temperature and the liquidus temperature of the relatively coarse prealloyed metal powder.

28. The method of claim 25, further comprising the step of providing the relatively coarse prealloyed metal powder, wherein the relatively coarse prealloyed metal powder consists of more than one metal alloy and each of said metal alloys is amenable to supersolidus liquid phase sintering, and said step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that is lower than the liquidus temperature of each of the relatively coarse prealloyed metal powder metal alloys.

29. The method of claim 28, wherein said step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that is lower than the solidus temperature of each of the relatively coarse prealloyed metal powder metal alloys.

30. The method of claim 28, wherein said step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that exceeds the solidus temperature of each of the relatively coarse prealloyed metal powder metal alloys.

31. The method of claim 25, further comprising the step of providing the relatively fine metal powder, wherein the relatively fine metal powder consists of more than one elemental

metal or metal alloy, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

32. The method of claim 25, wherein said step of forming a green article further comprises powder containerization.

33. The method of claim 25, wherein said step of forming a green article further comprises a free-forming layer-wise buildup technique.

34. The method of claim 33, wherein the free-forming layer-wise buildup technique is three-dimensional printing.

35. The method of claim 33, wherein the free-forming layer-wise buildup technique is selective laser sintering.

36. The method of claim 25, wherein said step of forming a green article further comprises metal injection molding.

37. The method of claim 25, wherein said step of forming a green article further comprises die pressing.

38. A method of densifying a green article, said method comprising the steps of:

a) mixing together a minor volume fraction of a relatively fine metal powder and complementary major volume fraction of a relatively coarse prealloyed metal powder to produce a metal powder mixture;

b) forming a green article from said metal powder mixture;

c) heating the green article to a sintering temperature that is below the liquidus temperature of the relatively coarse prealloyed metal powder; and

d) holding the green article at said sintering temperature for a time of sufficiently long duration to densify the green article;

wherein said minor volume fraction of a relatively fine metal powder consists of at least two sub-fractions of successively finer mean particle size, each of said successive sub-fractions consists of metal powder that is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, the ratio of the mean particle size of the coarsest of said successive sub-fractions to the mean particle size of the relatively coarse prealloyed metal powder is at least about 1:5, and the ratio of the mean particle size of each finer successive sub-fraction to the mean particle size of an immediately preceding coarser successive sub-fraction is at least about 1:5.

39. The method of claim 38, wherein the step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that is below the solidus temperature of the relatively coarse prealloyed metal powder.

40. The method of claim 38, wherein the step of heating the green article to a sintering temperature comprises heating the article to a sintering temperature that is between the solidus temperature and the liquidus temperature of the relatively coarse prealloyed metal powder.

41. The method of claim 38, further comprising the step of providing the relatively coarse prealloyed metal powder, wherein the relatively coarse prealloyed metal powder consists of more than one metal alloy and each of said metal alloys is amenable to supersolidus liquid phase sintering, and said step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that is lower than the liquidus temperature of each of the relatively coarse prealloyed metal powder metal alloys.

42. The method of claim 41, wherein said step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that is lower than the solidus temperature of each of the relatively coarse prealloyed metal powder metal alloys.

43. The method of claim 41, wherein said step of heating the green article to a sintering temperature comprises heating the green article to a sintering temperature that exceeds the solidus temperature of each of the relatively coarse prealloyed metal powder metal alloys.

44 The method of claim 38, further comprising the step of providing the relatively fine metal powder, wherein at least one of the successive sub-fractions consists of two or more elemental metals or metal alloys, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

45. The method of claim 38, wherein said step of forming a green article further comprises powder containerization.

46. The method of claim 38, wherein said step of forming a green article further comprises a free-forming layer-wise buildup technique.

47. The method of claim 46, wherein the free-forming layer-wise buildup technique is three-dimensional printing.

48. The method of claim 46, wherein the free-forming layer-wise buildup technique is selective laser sintering.

49. The method of claim 38, wherein said step of forming a green article further comprises metal injection molding.

50. The method of claim 38, wherein said step of forming a green article further comprises die pressing.

51. A method of layer-wise free-forming a green article, said method comprising the steps of:

a) mixing together a minor volume fraction of a relatively fine metal powder and a complementary major volume fraction of a relatively coarse prealloyed metal powder to produce a metal powder mixture; and

b) selectively binding together metal powder particles of the metal powder mixture within each metal powder layer of a sequentially applied series of metal powder layers to form the green article;

wherein the relatively fine metal is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, and the ratio of the mean particle size of the relatively fine metal powder to the mean particle size of the relatively coarse prealloyed metal powder is at least about 1:5.

52. The method of claim 51, wherein the step of selectively binding together metal powder particles includes selectively jet-spraying a fugitive binder onto the metal powder particles.

53. The method of claim 51, wherein the step of selectively binding together metal powder particles includes selectively scanning the metal powder particles with a laser beam.

54. The method of claim 51, further comprising the step of providing the relatively fine metal powder, wherein the relatively fine metal powder consists of more than one elemental metal or metal alloy, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

55. The method of claim 51, further comprising the step of providing the relatively coarse prealloyed metal powder, wherein the relatively coarse prealloyed metal powder consists of more than one metal alloy, each of said metal alloys being amenable to supersolidus liquid phase sintering.

56. The method of claim 51, wherein the step of selectively binding together metal powder particles includes using a mask to selectively expose the metal powder particles to light.

57. The method of claim 56, wherein the step of mixing includes making a slurry of the metal powder mixture and a volatile liquid, and wherein at least one metal layer of said sequentially applied series of metal powder layers is applied in the form of said slurry.

58. A method of layer-wise free-forming a green article, said method comprising the steps of:

a) mixing together a minor volume fraction of a relatively fine metal powder and a complementary major volume fraction of a relatively coarse prealloyed metal powder to produce a metal powder mixture; and

b) selectively binding together metal powder particles of the metal powder mixture within each metal powder layer of a sequentially applied series of metal powder layers to form the green article;

wherein said minor volume fraction of a relatively fine metal powder consists of at least two sub-fractions of successively finer mean particle size, each of said successive sub-fractions consists of metal powder that is essentially solid at the highest sintering temperature at which the green article can be sintered without slumping, the relatively coarse prealloyed metal powder is amenable to supersolidus liquid phase sintering, the ratio of the mean particle size of the coarsest of said successive sub-fractions to the mean particle size of the relatively coarse prealloyed metal

powder is at least about 1:5, and the ratio of the mean particle size of each finer successive sub-fraction to the mean particle size of an immediately preceding coarser successive sub-fraction is at least about 1:5.

59. The method of claim 58, wherein the step of selectively binding together metal powder particles includes selectively jet-spraying a fugitive binder onto the metal powder particles.

60. The method of claim 58, wherein the step of selectively binding together metal powder particles includes selectively scanning the metal powder particles with a laser beam.

61. The method of claim 58, further comprising the step of providing the relatively fine metal powder, wherein at least one of the successive sub-fractions consists of two or more elemental metals or metal alloys, each of said elemental metals or metal alloys being essentially solid at the highest sintering temperature at which the green article can be sintered without slumping.

62. The method of claim 58, further comprising the step of providing the relatively coarse prealloyed metal powder, wherein the relatively coarse prealloyed metal powder consists of more than one metal alloy, each of said metal alloys being amenable to supersolidus liquid phase sintering.

63. The method of claim 58, wherein the step of selectively binding together metal powder particles includes using a mask to selectively expose the metal powder particles to light.

64. The method of claim 63, wherein the step of mixing includes making a slurry of the metal powder mixture and a volatile liquid, and wherein at least one metal layer of said sequentially applied series of metal powder layers is applied in the form of said slurry.